Gallium arsenide fets for 144 and 432MHz

by John Regnault, G4SWX*

John Regnault is now in his fourth decade, married, and living in Ipswich. First licensed in 1972 as G8FQO after several years' active interest in the amateur bands. The morse test and Class A licence came only recently after many years of laziness, and when 180+ squares left little to be worked on 144MHz phone. Educated at Wimbledon College, and at UMIST in Manchester where he studied electrical engineering with alternative radio as a popular extra-curricular subject. Employed at British Telecom Research Laboratories at Martlesham on semiconductor device research, he has been working with GaAs and related semiconductors for over 10 years. With a keen interest in home construction, dx and contests, John has been a member of the Society's Technical & Publications Committee for the last year. Ambitions: 144MHz DXCC, full planning permission and no tvi.

Introduction

In the past few years some specialized amateur equipment has seen the introduction of gallium arsenide devices. Their use has been mainly restricted to the microwave buffs, and to the average amateur they are something of a black art. It is hoped that this article will open the "Pandora's Box" and provide a good general background in addition to constructional information for cheap GaAsfet amplifiers for the 144 and 432MHz bands.

The GaAsfets used on microwave frequencies and those used in preamplifiers for eme work were designed and manufactured for microwave use and are somewhat expensive. A new type of GaAsfet which has appeared on the market, is a dual-gate device designed for uhf use, and is being mass-produced for use in television tuners. These devices are being produced by many of the major semiconductor manufacturers, notably in Japan, and include the 3SK97, 3SK112 and S3000. Unlike the microwave fets these devices are rugged, have gate protection diodes, and cost very little more than silicon devices. When used properly dual-gate GaAsfets can provide excellent performance on 144 and 432MHz both as preamplifiers or as a replacement for an existing front-end device [1, 2].

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The GaAs device

The specific device chosen for this design is the 3SK97, which is a dual-gate depletion-mode Schottky gate fet. The Schottky gate relies on a metal semiconductor contact which behaves electrically in a similar fashion to a p-n junction, in fact the device symbol is the same as a junction field effect transistor (jfet). Inside the plastic there is a small gallium arsenide chip which will be less than 0.25mm². The construction and geometry of the device is relatively simple, and a schematic cross-sectional diagram is shown in Fig 1.

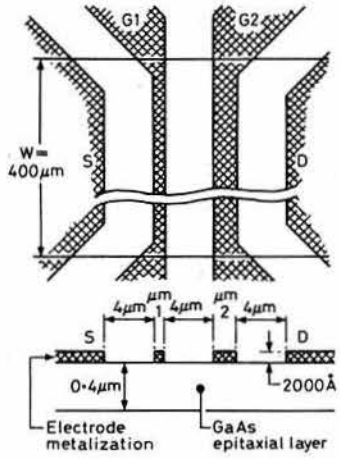


Fig 1. Schematic view of 3SK97 GaAsfet

The gates of GaAsfets, with their very small contact area (1μm × 400μm) with the semiconductor, are prone to damage due to electrostatic discharge. A gate current of 1mA would be equivalent to a current of 10A in 16swg wire! The 3SK97 has protective silicon diodes on each gate to prevent disasters. These protection diodes are mounted together with the GaAsfet chip in a small plastic package, this package is the same as that used in the 3SK88 silicon mosfet. The introduction of these protection diodes unfortunately degrades the noise figure by 0·3dB to give a device noise figure at 900MHz of about 1dB.

Biasing dual-gate GaAsfets is just as simple as for silicon mosfets, the only precaution is to ensure that the gates are never positively biased with respect to the channel. Reference to the data sheet gives the following conditions for best noise figure performance.

Vg1s	−1 to −2V
Vg2s	+2 to +4V
Vds	+5V
Id	15 to 20mA

These conditions are easily achieved in a self-biasing circuit, as shown in Fig 2.

In this circuit, which only requires one supply, gate 1 is grounded, and gate 2 bias is provided by a potential divider from the drain supply which is stabilized by a zener diode. The source bias and drain supply are adjusted by changing the value of the source resistor.

Preamplifiers for 144 and 432MHz

The electrical circuits of the 144 and 432MHz preamplifiers are identical and are shown in Fig 3. This circuit is similar to one using single-gate GaAs devices described by W6PO in an Eimac EME note [3]. The only differences between the 144 and 432MHz preamplifiers are in the input tuned circuit and the output matching transformer. A conventional coil and capacitor arrangement is used on the input of the 144MHz preamplifier, whereas a tuned stripline is used in the 432MHz version.

It is important to obtain good-quality capacitors for C1 and C2 in order to keep losses in the input matching circuit to a minimum. Several prototypes have been constructed using surplus glass piston trimmers purchased at rallies; suitable types are manufactured by JFD and Oxley. Untuned toroid transformers were chosen for the output matching for ease of construction and good stability. As the gain of both preamplifiers using toroidal transformers when noise matched was found to be over 23dB, tuned matching was not attempted. Larger-sized toroids have been tried for T1; however, the stability of the amplifier was not good and oscillation occurred at about 2GHz. As both cores used are readily available in the UK, the author did not experiment further, although other types may be suitable.

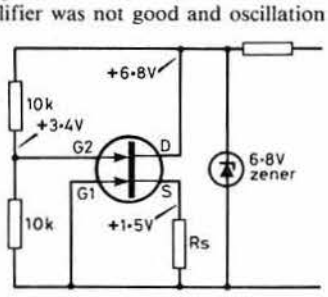


Fig 2. Biasing of 3SK97 dual-gate GaAsfet

Components list

C1, 2	6 or 10pF max glass piston trimmers
C3, 4	1nF leadless disc ceramic
C5	0·1μF disc ceramic
C6	1nF disc ceramic
C7	1nF feedthrough
R1, 2	10kΩ
R3	100Ω
R4	220Ω
TR1	3SK97 GaAsfet
D1	6·8V zener diode 400mW
L1	144MHz 6t 14swg 6mm id, 13mm long; 432MHz Copper line 15mm wide, 57mm long, spaced 4mm above groundplane
T1	144MHz 12t twisted pair of 26swg enamelled copper wire; 432MHz 5t two windings connected in series as 4:1 transformer on Amidon t20-12 toroid core

Note: Ferrite beads are fitted to R1 and D1 as in the circuit.

Construction

Both preamplifiers were built in small diecast boxes 3·5 by 1·5 by 1·25in, RS part No 509-923. BNC connectors were used on the 144MHz version, and SMC connectors on the 432MHz version because of their small size.

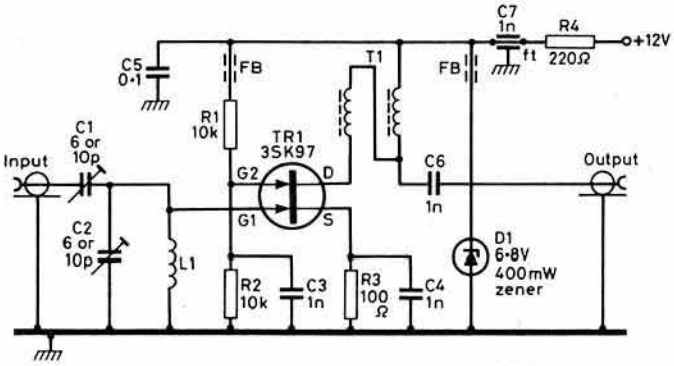
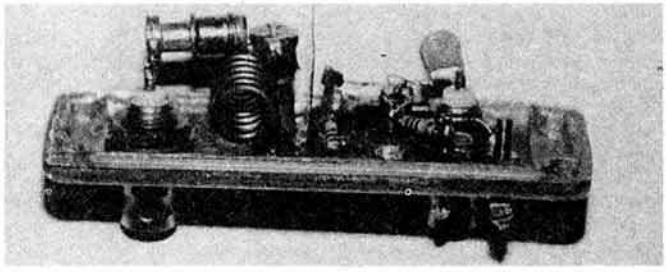


Fig 3. GaAsfet preamplifier for 144 or 432MHz

The layout is shown in Figs 4 and 5. A piece of double-sided pcb was cut to fit the lid of the box, and this acts as a groundplane for mounting most of the components. A vertical screen of pcb or tinplate separates the input and output. The leadless disc ceramic capacitors C3 and C4 are soldered on either side of a hole drilled in the screen for the gate 1 lead. It is important to mount the larger components (C1, C2, L1) first, as these require the most soldering. The fet is the last component to be soldered. Leave only the shortest possible lead length between the drain of TR1 and the output transformer. Fig 6 shows the base connections of the 3SK97, the drain lead being the longest. When soldering the fet into circuit observe the normal precautions used when handling static sensitive devices. A well-earthed soldering iron is essential, and the fet should be soldered using the minimum of heat necessary.



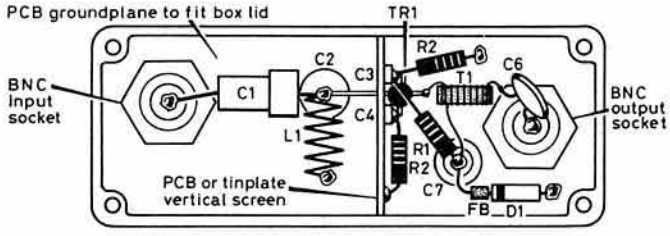
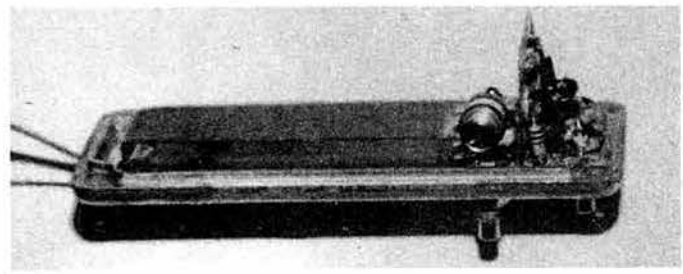


Fig. 4. Photograph and layout of 144MHz preamplifier. The resistor connecting the screen and C4 is R3, not R2. R4, not shown, is on the outer side of the box



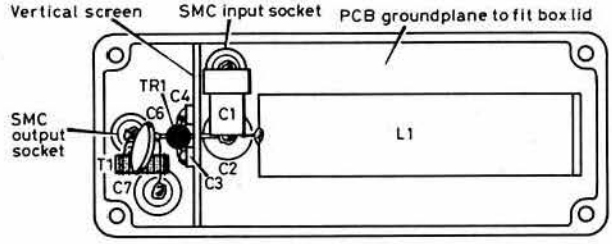


Fig 5. Photograph and layout of 432MHz preamplifier. Resistors have been omitted for the sake of clarity

Testing and alignment

To check for major mistakes in construction, the wary may choose to check the circuit before soldering the GaAsfet into position. The current drawn should be 25-30mA, and this should not change much when the device is in place. Alignment of the rf circuitry should ideally be done using some form of automatic noise figure optimization system; the alignment aid described by G4COM [4] is ideal.

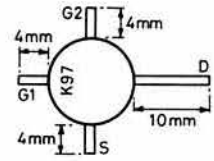


Fig 6. Base connections of 3SK97

For those without such luxuries, alignment on the air using a weak signal has to suffice. One method used by the author with great success is to use a variable attenuator between the preamplifier and the receiver, and using a weak fm signal to tune up the preamplifier. Tune the preamplifier initially for maximum signal, then slowly decrease C1, re-adjusting C2 for best signal-to-noise until an optimum is found.

Conclusions

Several preamplifiers have been built for each band, and noise figures of less than 1dB were measured on all of them. Power gains of 26dB for the 144MHz version, and 23dB for the 432MHz version were typical; one amplifier, however, did show signs of instability. If instability does occur, or is suspected, it can usually be cured by fitting a ferrite bead over the drain lead close to the fet. This reduces the gain of the 432MHz preamplifier to 20dB but has negligible effect on the 144MHz one.

If the preamplifier is to be used in front of an existing receiver, an attenuator should be inserted between them so that the dynamic range of the receiver is not seriously degraded. The method to calculate the required value of this attenuator was described by G3YGF [5]. A suitable value of attenuator to match a typical transceiver with a noise figure of 6dB would be 13dB. The author has constructed a 432MHz transverter using a 3SK97 front-end and a diode ring mixer; the transverter noise figure was measured at less than 2dB, which represents "state-of-the-art" performance.

References

[1] "Technical Topics", Pat Hawker, G3VA. *Rad Com* February 1982, pp 141-2.

[2] "Technical Topics", Pat Hawker, G3VA. *Rad Com* December 1983 pp 1083-4.

[3] "Some GaAsfet preamplifiers", R. Sutherland, W6PO. EIMAC EME Note.

[4] "An alignment aid for vhf receivers", J. R. Compton, G4COM. *Rad Com* January 1976, pp 36-8.

[5] "The effects of preamplifiers on receiver performance, and a review of some currently available 144MHz preamplifiers", J. N. Gannaway, DPhil, G3YGF, *Rad Com* November 1981, pp 1026-31. □